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OIL SHALE ASH AND CEMENT KILN FLUE DUST AS
LIMING FERTILIZERS

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klinkernoy pyli kak izvestkovykh udobreniy]

E. Turbas, V. Khiys, and P. Kuldkepp

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THE CHEMICAL COMPOSITION AND EFFECTIVENESS OF OIL SHALE ASH AND CEMENT KILN FLUE DUST AS LIMING FERTILIZERS

E. Turbas,* V. Khiys,** and P. Kuldkepp***

According to the investigations of A. Khallik, after World War II the extensive use of local limnetic liming materials (lime tuff and lake lime) was begun in the Estonian SSR to neutralize the acidity of soil. It soon also became clear that oil shale ash was even more effective than lime tuff and lake lime. On the basis of the investigations conducted by A. Khallik, the use of oil shale ash in acid soil was adopted.

Today, only shale ash and clinker (cement) dust are employed in the Estonian SSR for liming acid soils. Of the total amount of employed lime fertilizers, more than 70% are made up by dust materials - dust oil shale ash and cement dust, although the use of the latter was only begun in 1964. The named waste products are ideally fine and are absolutely dry.

The Chemical Composition of Lime Fertilizers

The chemical composition of lime fertilizers, based on analyses made in the years 1966-1968 and employed in the Estonian SSR is given in Table 1. These data show that oil shale ash and cement dust have a quite high neutralizing capacity and contain such nutrients, in addition to calcium, as sulfur, potassium and magnesium, which are comparatively well soluble.

* Assistant Professor, Candidate of Agricultural Sciences.

** Senior Scientific Associate, Candidate of Agricultural Sciences.

*** Senior Instructor, Candidate of Agricultural Sciences.

The Department of Soil Sciences and Agrochemistry

TABLE 1.

CHEMICAL COMPOSITION OF OIL SHALE ASH AND CEMENT DUST (MEAN CONTENT IN DRY SUBSTANCE OF SAMPLES IN %: ANALYSES OF 1966-1968)

Lime ferti- lizer ¹	No. of sam- ples	Neutral- izing capa- city, CaCO ₃	CaO	MgO	K ₂ O	SO ₃	P ₂ O ₅	SiO ₂	R ₂ O ₃	CO ₂
Bulk Content										
1	7		41.5	4.4	3.6	7.6	0.21	29.8	13.7	1.1
2	12		46.6	4.5	2.5	4.7	0.20	26.9	12.4	2.8
3	3		54.1	5.1	1.8	3.2	0.19	22.8	11.9	2.1
4	1		41.5	4.5	2.5	5.1	0.17	30.1	13.5	3.2
5	16		42.6	3.1	5.2	6.9	0.18	13.8	6.7	21.5
6	5		34.5	2.4	1.9	4.2	0.18	28.4	11.3	8.3
Soluble in 1 n. HCl										
1	6	67.1	38.2	3.6	2.5	7.3	—	10.0	9.1	
2	13	81.6	44.4	3.9	1.7	4.5	0.14	10.6	8.8	
3	3	92.5	48.7	4.1	1.3	2.9	—	10.7	8.4	
4	1	68.9	37.3	3.6	1.8	4.8	—	10.1	9.2	
5	16	74.9	41.6	2.6	4.8	5.6	0.34	5.1	4.5	
6	5	56.9	33.2	1.9	1.0	3.8	0.14	9.5	8.0	
Water Soluble Content										
1	6	19.2	12.6	0.2	0.4	2.4	traces			
2	12	19.0	12.0	0.2	0.1	1.7	"			
3	3	22.5	13.8	0.1	0.0	1.4	"			
4	1	20.1	13.1	0.1	0.1	2.4	"			
5	16	1.9	2.6	0.2	3.8	4.2	0.04			
6	5	10.2	4.2	0.2	0.2	1.0	traces			

- ¹ 1 — Electrofilter oil shale ash from the Pribaltic GRES.
 2 — Cyclone filter oil shale ash from the Pribaltic GRES.
 3 — Chamber filter oil shale ash from the Pribaltic GRES.
 4 — Cyclone filter oil shale ash from the Kikhtla-Yarveskaya TES
 5 — Cement dust from the "Punane Kunda" cement factory
 6 — Grate oil shale ash.

The neutralizing capacity is particularly high in the powdered oil shale ash (electrofilter, cyclone, and grate chamber ash), while the largest powdered shale ash (chamber ash) also has the highest neutralizing capacity and the maximum content of calcium and magnesium. With an increase in fineness of the powdered ash, its neutralizing capacity decreases and the content of potassium and sulfur increases. The content of phosphorous is low in the lime fertilizers.

Cement dust is similar to the powdered oil shale ash with respect to its chemical composition and other properties. It still differs from powdered oil shale ash in its carbonate content and higher content of potassium, and in its easier solubility of potassium and sulfur compounds.

Our powdered lime fertilizers also contain small amounts of trace elements required for plants, whose bulk content is given in Table 2. These data show that the content of trace elements in the powdered oil shale ash and cement dust is not great. All the same, when liming soils with these materials, about 1-2 kg of trace elements are introduced per hectare.

TABLE 2.

CONTENT OF TRACE ELEMENTS IN POWDERED LIME FERTILIZERS (IN MG PER 1 KG: NUMBER OF SAMPLES: POWDERED OIL SHALE ASH - 15, CEMENT DUST - 4)

Element	Powdered oil shale ash		Cement dust	
	Fluctuations	Mean	Fluctuations	Mean
Boron	4...23	15.8	7...10	8.6
Copper	8.6...15.5	12.6	6.0...45.0	23.1
Manganese	145...205	168.0	190...215	203.0
Molybdenum	6.0...15.5	10.8	3.0...4.0	3.8
Cobalt	1.90...3.75	2.56	1.75...2.85	2.15
Zinc	28...126	69.0	18...126	74.0

On the basis of 193 samples of powdered oil shale ash analyzed in 1967-1969 and employed for liming soils, its neutralizing capacity averages 85.1% when corrected for CaCO_3 . The same indicator in the grate oil shale ash is significantly lower and on the basis of 38 samples comprises 63.5% CaCO_3 in the dry, non-ballast material. In the same span of time, cement dust had a neutralizing capacity averaging 75.0% with correction for CaCO_3 and based on an analysis of 231 samples, and contained 4.8% K_2O soluble in 1 n. hydrochloric acid.

Field Trials in Sod-Podzol Soil

The effect of powdered electrofilter oil shale ash under the influence of lime tuff and grate oil shale ash used for liming acid soils before the

application of powdered materials were compared in 5 field trials. The effect of liming the soil was studied against 4 fertilizer backgrounds in the same trials: without fertilizer, NP, NPK and NPK + manure.

The examined field trials were set up in 1964 in sod-moderately podzol loams or sandy loam soils in 3 farms in the southeastern part of Estonia.

The soil in all of the trials was strongly acid (pH_{KCL} 4.2-5.0, hydrolytic acidity 3.7-5.2 mg/equiv. per 100 g. soil), with a low degree of saturation (33-59%), and in most cases with a high content of mobile aluminum (1.0-6.4 mg per 100 g soil). The humus content of the soil was low (1.3-2.1%). The content of lactate-soluble phosphorous was low or even very low (1.5-7.5 mg P_2O_5 per 100 g soil), the content of lactate-soluble potassium was generally average (3-18 mg K_2O per 100 g soil).

Lime fertilizers were introduced when setting up the trials in the half-norm of hydrolytic acidity of the plowed layer. Depending on the neutralizing capacity of the lime materials, lime tuff was introduced in the amount of 3.49-4.61 t per hectare, electrofilter oil shale ash in the amount of 3.48-4.14 t and grate oil shale ash - 7.65-9.61 t per hectare.

Of the mineral fertilizers, ammonium nitrate was annually applied in the amount of 1.5-2 centners/ha (besides pasture grasses, which were not given nitrogen), superphosphate in the amount of 3-3.5 centners per hectare and potassium salt in the amount of 3-4 centners per hectare. Manure was applied in the appropriate variations in the course of preplanting treatment of the soil, usually in the amount of 30 t/ha.

The tests were conducted according to a widely accepted method with 4 repetitions. The total area of experimental fields was 124 m².

From data on the harvest, one can see (Tables 3 and 4) that of the grain crops, barley and spring wheat reacted to liming the soils better (in comparison with oats and winter rye). Pasture grasses (clover + timothy) reacted ex-

tremely strongly to liming the soil. Noticeable increments resulting from liming were also obtained in corn and the potato.

There was a sharp increase in the specific weight of clover in the hay harvest under the effect of liming the soil. If in hay collected from unlimed soils the specific weight of clover fluctuated within limits ranging from 10 to 40%, then in hay from limed soil the proportion of clover increased to 80%. In this case, oil shale ash produced systematically better results than lime tuff in each crop and against each background. As an example, we shall cite data of the clover content in a hay harvest collected in 1967 in the first crop from pasture grasses of the first year of use: without liming (NP background) - 11.7%, with lime tuff - 30.0%, with grate oil shale ash - 63.2%, with electrofilter oil shale ash - 63.8%. Hence, the lime fertilizers also noticeably improved the quality of the hay in addition to increasing the total harvest.

TABLE 3.
THE EFFECT OF LIME FERTILIZERS ON THE HARVEST OF GRAIN CROPS AGAINST
VARIOUS BACKGROUNDS OF FERTILIZER (CENTNERS/HA)

Background	Lime Fertilizer	Barley (7 harvests)		Spring wheat (2 harvests)		Oats (1 harvest)		Winter rye (3 harvests)	
		Har- vest	Incre- ment of harvest	Har- vest	Incre- ment of harvest	Har- vest	Incre- ment of harvest	Har- vest	Incre- ment of harvest
Without fertilizer	-	13.0	—	9.1	—	14.8	—	15.6	—
	Lime tuff	15.1	2.1	11.6	2.5	15.0	0.2	16.5	0.9
	Grate oil shale ash	15.6	2.6	13.8	4.7	14.9	0.1	19.7	4.1
	Electro- filter oil shale ash	16.2	3.2	13.5	4.4	15.8	1.0	17.8	2.2
NP	-	18.9	—	13.0	—	25.9	—	22.9	—
	Lime tuff	23.5	4.6	17.1	4.1	26.0	1.0	24.7	1.8
	Grate oil shale ash	24.8	5.9	18.9	5.9	28.3	2.4	25.0	2.1
	Electro- filter oil shale ash	25.6	6.7	18.0	5.0	28.2	2.3	25.2	2.3

TABLE 3. (Continued)

NPK	-	23.3	-	17.1	-	26.4	-	23.5	-
	Lime tuff	28.9	5.6	20.1	3.0	28.1	1.7	25.3	1.8
	Electro-	30.0	6.7	22.0	4.9	31.7	5.3	26.7	3.2
	filter oil shale ash								
NPK + manure	-	31.5	-	26.0	-	28.0	-	26.0	-
	Lime tuff	34.3	2.5	25.0	4.1	29.9	1.9	27.0	1.0
	Electro-	35.3	3.5	25.6	4.7	32.0	4.0	28.8	2.8
	filter oil shale ash								
	HCP _{95%}		3.2		2.1		1.7		2.6
	HCP _{99%}		4.3		2.8		2.3		3.3
	HCP _{99.9%}		5.5		3.6		3.1		4.4

A significant change in the quality of the harvest under the effect of lime fertilizers was also observed in the potato. In the first year of its effect, lime fertilizers applied in Spring even caused a slight decrease in the starch content of the tubers. But in succeeding years, their effect on the starch content became positive. A large increase in the starch content was noted against the non-fertilizer background and also against a background of NPK-fertilizer. Due to the harmful effect of chlorine applied as a part of the potassium salt, in spring the content of starch sharply dropped. Although the harvest of tubers under the effect of potassium salt also significantly increased, the harvest of starch in certain cases even dropped (in 1966- by 10%). The lime fertilizers reduced the negative effect of chlorine, due to which the harvests of starch increased to a relatively greater degree than the harvest of tubers.

The mineral fertilizers and manure applied as a background significantly increased the harvests of test crops. Lime fertilizers had little influence on the effectiveness of mineral fertilizers in corn and the potato, but in grain crops, and particularly in pasture grasses, liming the soils significantly increased the effectiveness of the applied mineral fertilizers. Thus, the average harvest of hay increased under the effect of mineral fertilizers: without the use of lime fertilizers - 3.5 centners per hectare, with the use

of lime tuff - by 10.2 centners per hectare, and with the use of electrofilter oil shale ash - by 8.8 centners per hectare. The corresponding figures in barley were 10.3, 13.8, and 13.8 centners per hectare.

TABLE 4.

THE EFFECT OF LIME FERTILIZERS ON THE POTATO HARVEST, THE GRAIN MASS OF CORN AND HAY OF PASTURE GRESSES AGAINST VARIOUS FERTILIZER BACKGROUNDS (CENTNERS/HA)

Background	Lime Fertilizer	Potato (4 harvests)				Corn (1 harvest)		Pasture grasses (6 harvests)	
		Tuber harvest	Increment of tuber harvest	Starch harvest	Increment of starch harvest	Harvest	Increment of harvest	Harvest	Increment of harvest
Without fertilizer	-	110	—	21.5	—	323	—	23.7	—
	Lime tuff	125	15	25.2	3.7	396	73	34.9	11.2
	Grate oil shale ash	140	30	27.1	5.6	394	71	40.6	16.9
	Electrofilter oil shale ash	136	26	27.5	6.0	406	83	41.2	17.5
NP	-	179	—	36.2	—	405	—	27.2	—
	Lime tuff	186	7	37.3	1.1	467	62	42.8	15.6
	Grate oil shale ash	209	30	41.9	5.7	486	81	46.9	19.7
	Electrofilter oil shale ash	194	15	39.3	3.1	482	77	47.3	20.1
NPK	-	212	—	36.8	—	439	—	27.2	—
	Lime tuff	220	8	38.9	2.1	512	73	45.1	17.9
	Electrofilter oil shale ash	222	22	41.2	4.4	510	79	50.0	22.8
NPK + manure	-	261	—	44.0	—	518	—	41.7	—
	Lime tuff	269	8	45.6	1.6	552	34	54.0	12.3
	Electrofilter oil shale ash	270	9	45.9	1.9	570	52	58.5	16.8
	HCP95%		15				69		5.4
	HCP99%		19				93		7.1
	HCP99.9%		25				121		9.1

Liming the soils reduced the effectiveness of systematically applying manure. With respect both to the effectiveness of mineral fertilizers and the effectiveness of manure, the various lime fertilizers had an identical effect. For example, the mean barley harvest increased as the result of employing manure: in unlimed soil - by 8.5 centners per hectare, in soil limed with tuff - 5.4 centners per hectare, and in soil limed with electrofilter oil shale ash - by 5.3 centners per hectare. In pasture grasses the corresponding figures are 14.5, 8.9, and 8.5 centners per hectare.

If one compares the effect of various lime fertilizers it becomes clear that in all crops and against all backgrounds of lime ash, both the grate and electrofilter type, provided more noticeable increments in the harvest than did lime tuff. No significant differences were observed in the effect of grate and electrofilter oil shale ash.

The mean harvest increments from lime fertilizers were highest against a background of NPK and became least with the heavy application of fertilizer (Table 5). A strong deficiency of nutrients in the soil also noticeably reduced the effectiveness of lime fertilizers. In comparison with the effect of lime tuff, oil shale ash ensured the highest relative increment against a background of no fertilizer.

The field tests were also conducted under the same conditions in which the effect of different types of powdered lime materials was compared. In these experiments, all types of powdered oil shale ash and cement dust applied in 1964 at the half-norm for hydrolytic acidity of the plowed layer of the soil proved to be almost identical in value for grain crops (Table 6). All the same, and practically as a rule, the increments resulting from chamber oil shale ash were systematically least while the increments resulting from the use of cement dust were greatest. The mean increments of harvests from lime fertilizers against both backgrounds were practically identical.

A noticeable advantage of cement dust was noted in the potato (Table 7), especially in the first year of the effect of lime fertilizers, since with

TABLE 5.

MEAN HARVEST INCREMENTS UNDER THE EFFECT OF LIME FERTILIZERS AGAINST
DIFFERENT FERTILIZER BACKGROUNDS (BASED ON 24 HARVEST ESTIMATES)

Background	Lime fertilizer	Increment in seed units from 1 hectare per year	Relative effect of lime fertilizers		
			Lime tuff = 100	Increment against a background of NPK=100	
				Lime tuff	Electro- filter oil shale ash
Without fertilizer	Lime tuff	380	100	66	
	Grate oil shale ash	612	161		
	Electrofilter oil shale ash	612	161		76
NP	Lime tuff	509	100	88	
	Grate oil shale ash	772	152		
	Electrofilter oil shale ash	721	142		89
NPK	Lime tuff	578	100	100	
	Electrofilter oil shale ash	808	140		100
NPK + manure	Lime tuff	370	100	64	
	Electrofilter oil shale ash	525	142		65

the spring introduction of free CaO, contained in the fresh powdered oil shale ash, the latter could exert a negative effect on the potato. The powdered lime fertilizers did not have a significant effect on the starch content in the tubers against the NP background but reduced the negative effect on the starch content resulting from applying chlorine together with the potassium fertilizer. Due to this, starch harvests under the effect of lime fertilizers increased to a relatively greater degree than the harvest of tubers.

Hay harvests more than doubled under the effect of lime fertilizers.

Lime fertilizers produced more significant harvest increments in the potato and pasture grasses against a background of using potassium fertilizer.

TABLE 6.

THE EFFECT OF DIFFERENT POWDERED LIME FERTILIZERS ON THE HARVEST OF GRAIN CROPS (CENTNERS PER HECTARE)

Background	Lime fertilizer ¹	Barley		Spring wheat		Oats	
		(7 harvests)		(2 harvests)		(1 harvest)	
		Harvest	Harvest incre- ment	Harvest	Harvest incre- ment	Harvest	Harvest incre- ment
NP	-	15.6	—	13.7	—	24.8	—
	Electrofilter oil shale ash	22.5	6.9	18.2	4.5	27.4	2.6
	Cyclone oil shale ash	22.0	6.4	17.4	3.7	27.8	3.0
	Chamber oil shale ash	25.0 ²	6.1 ²	19.2 ³	4.6 ³	26.9	2.1
	Cement dust	22.7	7.1	17.7	4.0	29.5	4.7
NPK	-	19.2	—	16.7	—	26.1	—
	Electrofilter oil shale ash	25.6	6.4	20.4	3.7	30.7	4.6
	Cyclone oil shale ash	24.9	5.7	20.2	3.5	29.0	2.9
	Chamber oil shale ash	24.6	5.4	19.4	2.3	29.7	3.6
	Cement dust	25.7	6.5	20.9	4.2	31.2	5.1
	HCP95%		2.0		2.0		3.3
	HCP99%		2.6		2.7		4.4
	HCP99.9%		3.3		3.5		5.8

¹elf. — Electrofilter oil shale ash, cycl.- cyclone oil shale ash, cham.- chamber oil shale ash, cl.- cement dust

² 5 harvests

³ 1 harvest

According to the mean data of all estimates of the harvest (Table 8), cement dust produced a more significant increment than oil shale ash. Cement dust was more effective against a background without potassium fertilizer, which indicates assimilation of the potassium from cement dust. All types of powdered oil shale ash containing less potassium were more effective against an NPK background. Of the various kinds of powdered oil shale ash, electrofilter oil shale ash was distinguished by higher effectiveness. This is explained by the fact that electrofilter ash, in comparison with the other kinds of powdered oil shale ash, contains more nutrients and less lime. Due to its lesser neutralizing capacity, it was applied in larger gravimetric amounts than the others.

In the years 1964-1967, 4 field tests were carried out to clarify the effectiveness of oil shale ash and cement dust in turf-podzol soils formed in carbonate moraine.

TABLE 7.

THE EFFECT OF VARIOUS POWDERED LIME FERTILIZERS ON THE HARVEST OF POTATOES AND HAY OF PASTURE GRASSES (CENTNERS PER HECTARE)

Background	Lime Fertilizer	Potato (5 harvests)				Pasture grasses (2 harvests)	
		Harvest of tubers	Increment of tuber harvest	Harvest of starch	Increment of starch harvest	Hay harvest	Harvest increment
NP	-	175	—	34,5	—	15,0	—
	Electrofilter oil shale ash	193	18	38,6	4,1	32,4	17,4
	Cyclone filtered oil shale ash	185	10	39,1	4,6	30,0	15,0
	Chamber oil shale ash	198 ¹	10 ¹	39,3 ¹	2,5 ¹	35,9 ²	18,7 ²
	Cement dust	220	45	43,3	8,8	32,9	17,9
NPK	-	205	—	35,6	—	15,0	—
	Electrofilter oil shale ash	229	24	40,8	5,2	38,6	23,6
	Cyclone filtered oil shale ash	221	16	40,1	4,5	35,7	20,7
	Chamber oil shale ash	221	16	39,3	3,7	35,8	20,8
	Cement dust	240	35	42,7	7,1	38,3	23,3
	HCP _{95%}		20,3				3,9
	HCP _{99%}		26,7				5,3
	HCP _{99.9%}		34,3				6,9

¹ 3 harvests

² 1 harvest

Two experiments were conducted on turf-moderately podzol sandy loam soils whose agrochemical indices in the plowed layer were the following: humus content 2.2%, pH_{KCL} - 4.2-5.0, hydrolytic acidity - 3.8-6.6 mg/equiv. per

100 g soil, degree of base saturation 30-70%, content of mobile aluminum - 0.4-6.0 mg and content of lactate-soluble K_2O - 10-17 mg per 100 g soil. The remaining 2 experiments were conducted on turf-mildly podzol sandy loam whose plowed layer is characterized by the following data: humus content 2.4%, pH_{KCL} - 4.4-5.0, hydrolytic acidity - 3.8-5.5 mg/equiv. per 100 g soil, degree of saturation 50-74%, content of mobile aluminum 0.4-1.6 mg, and content of lactate-soluble K_2O 3-9 mg per 100 grams of soil.

TABLE 8.

MEAN INCREMENTS OF HARVEST UNDER THE EFFECT OF VARIOUS POWDERED LIME FERTILIZERS (ON THE BASIS OF 17 HARVEST ESTIMATES)

Background	Lime Fertilizer	Mean increments in feed units from 1 hectare per year	Relative effect of lime fertilizers
NP	Electrofilter oil shale ash		
	Cyclone oil shale ash	728	120
	Chamber oil shale ash	608	100
	Cement dust	622 ¹	104
NPK	Electrofilter oil shale ash	989	163
	Electrofilter oil shale ash	788	122
	Cyclone oil shale ash	647	100
	Chamber oil shale ash	607	94
	Cement dust	902	139

¹ 11 harvests

Table 9 gives harvest increments obtained in these trials under the effect of cement dust and electrofilter oil shale ash over the course of the entire period of the experiment, i.e., for 2-4 years. Lime fertilizers were introduced when setting up the trials, generally in the amount of the half-norm for hydrolytic acidity. The norms for cement dust and electrofilter oil shale ash fluctuated from 3.5 to 4.3 tons per hectare. But in the trials in turf-moderately podzol soil, cement dust was introduced against a NP background in the amount of 1.2 t/ha, i.e., equivalent to the amount of potassium fertilizer.

The data on the harvest increments show that both powdered lime fertilizers under the given conditions also significantly increase harvests of test crops.

TABLE 9.

INCREMENTS IN HARVEST OBTAINED AS THE RESULT OF APPLYING CEMENT DUST AND ELECTROFILTER OIL

Soil ¹	Year	Crop	Cement dust			Electrofilter oil shale ash		
			NP-background	Cent-feed	NP-background	NP-background	Cent-feed	NP-background
			ners per hectare	units per hectare	ners per hectare	ners per hectare	units per hectare	ners per hectare
Pd ²	1964	Barley	3.8	422	3.4	3.2	376	2.3
	1965	Corn	91	1247	94	66	904	53
	Total			1669			1280	982
Pd ²	1964	Potato						
	1965	Barley	1	30	-3	20	605	-1
	Total		-0.6	-67	3.2	5.9	656	1.6
Pd ¹	1964	Potato						
	1965	Barley	15	454	8	-3	-91	-10
	1966	Barley	2.0	222	1.8	1.9	211	1.0
Pd ¹	1966	Barley	0.3	33	0.0	-0.7	-78	1.3
	Total			709			42	-25
Pd ¹	1964	Barley	2.4	267	3.3	1.6	178	0.8
	1965	Pasture	13.3	605	18.9	12.6	673	12.5
	1966	Pasture	6.4	291	2.1	5.4	245	1.0
Pd ¹	1967	Pasture	12.0	546	-2.0	5.9	208	0.7
	Total			1709			1264	734
On the average for 1 test				1012			937	460

¹ Pd² turf-moderately podzol sandy loam
 turf-mildly podzol [word missing in copy] (illegible)

In this case, the increments were more noticeable in the nonpotassium background. Cement dust ensured significantly better results than oil shale ash.

Field Trials in Turf-Carbonate Soils

In the spring of 1967, a field trial was set up in high alkali turf-carbonate soil. Ph_{KCl} of the soil of the plowed layer was 5.6-5.8, degree of base saturation 77-80%, and content of lactate-soluble potassium 5-6 mg per 100 g of soil. In setting up the experiment, cement dust was applied (neutralizing capacity 75.3% CaCO_3 , content of K_2O soluble in 1 n. hydrochloric acid 5.4%), and grate oil shale ash (56.7% CaCO_3 , 0.9% K_2O). The effect of lime materials was compared with the effect of potassium salt, which had been applied for 2 years running in the amount of 2 centners per hectare.

The data given in Table 10 show that in the first year barley produced a significant harvest increment resulting from the application of potassium salt and cement dust. Oats reacted weakly to both of the above named fertilizers. Grate oil shale ash did not provide a harvest increment.

TABLE 10.

THE EFFECT OF POTASSIUM SALT AND POTASSIUM-CONTAINING LIME FERTILIZERS
ON HIGH ALKALI TURF-CARBONATE SOIL (CENTNERS/HA)

Variation of test	Barley		Oats	
	Harvest	Harvest increment	Harvest	Harvest increment
1. NP	11.2	-	21.4	-
2. NP + potassium salt, 2 centners per hectare	14.4	3.2	23.3	1.9
3. NP + cement dust, 4 t/ha	15.1	3.9	21.6	0.2
4. NP + grate oil shale ash, 4 t/ha	11.8	0.6	20.3	-1.1
HCP ^{95%}		2.0		2.3
HCP ^{99%}		3.0		

In 1968, an experiment was set up in turf-gley soil (pH_{KCl} mainly 6.0-7.1, content of lactate-soluble K_2O - 6-13 mg per 100 g soil). The effect of cement dust (75.9% CaCO_3 , 3.6% K_2O) and cyclone oil shale ash (72.9% CaCO_3 ,

2.0% K_2O) was compared with the effect of potassium chloride.

In the year of setting up the experiment, both lime waste products and potassium fertilizer did not significantly increase the harvest of hay of the oat and pea mixture (Table 11). The next year, the pasture perennial grasses yielded a significant harvest increment under the effect of cement dust, but oil shale ash did not practically change the harvest. Potassium chloride somewhat increased the harvest without introducing the lime materials.

TABLE 11.

THE EFFECT OF POTASSIUM CHLORIDE, CEMENT DUST AND POWDERED OIL SHALE ASH ON THE HAY HARVEST IN TURF-GLEY SOIL (CENTNERS/HECTARE)

Variation of experiment	Hay mixture				
	Harvest	Harvest increment for pasture grasses	Harvest	Harvest increment	
				From lime materials	From potassium chloride
1. Background (NP or P)	25.4	—	48.4	—	—
2. K_{120} each year	26.9	1.5	53.4	—	5.0
3. K_{360} at setup	25.7	0.3	51.9	—	3.5
4. Cement dust, 2 t/ha each year	26.6	1.2	55.3	6.9	—
5. Cement dust, 4 t/ha at setup	26.0	0.6	58.4	10.0	—
6. Cement dust, 8 t/ha at setup	26.2	0.8	62.6	14.2	—
7. Cement dust, 4 t/ha at setup + K_{120} each year	26.7	1.3	56.9	3.5	-1.5
8. Cyclone oil shale ash, 4 t/ha at setup	26.4	1.0	52.1	3.7	—
9. Cyclone oil shale ash, 4 t/ha at setup + K_{120} each year.	28.8	3.4	53.0	-0.4	0.9
HCP		4.6		6.0	
95% HCP		6.7		8.7	
99% HCP					

Besides the examined trials in turf-carbonate soils in employing cement dust and oil shale ash, 6 more field tests were conducted, but no positive results were obtained from employing lime materials or potassium fertilizer. pH_{KCl} of the soil in these tests was 5.3-7.3 and the lactate-soluble K_2O was 4-21 mg per 100 grams of soil.

Savings Resulting from Employing Cement Dust and Oil Shale Ash

All of the lime fertilizers employed in our experiments in soils underlain with noncarbonate moraine provided a very high degree of profit - more than 1,000%. The cost per feed unit of harvest increment was significantly below 1 c. The use of powdered lime fertilizers on strongly and moderately acid soils underlain with carbonate bedrock is also well recouped.

In turf-carbonate soils, it may be expedient to employ cement dust or even electrofilter oil shale ash, primarily in place of potassium fertilizer. Taking as our basis expenditures in employing moderate amounts of powdered materials during transport with trucks, and the mean cost of harvest of crops in the state farms and collective farms of the Estonian SSR, we calculated the minimum harvest increments which recoup expenditures (Table 12).

TABLE 12.

EXPENDITURES IN EMPLOYING POTASSIUM-CONTAINING POWDERED LIME WASTE PRODUCTS IN THE AMOUNT OF 3 t/ha AND MINIMUM HARVEST INCREMENTS RECOUPING THESE EXPENDITURES.

Length of transport in km	General expenditures per hectare, in rubles	Minimum harvest increment in centners per hectare, recouping expenditures			
		Summer grain crops	Winter rye	Pasture grasses	Potato
10	6.06	0.9	0.7	2.9	1.4
50	10.83	1.5	1.3	5.2	2.4
100	14.67	2.1	1.7	7.1	3.2
150	20.04	2.9	2.3	9.6	4.4
200	25.38	3.6	3.0	12.2	5.6

The calculation provided shows that with a transport distance of up to 150 kilometers, the use of powdered lime fertilizers may prove profitable even with harvest increments of 1-3 centners per hectare or up to 5 centners of potatoes. Hence, the use of cement dust and powdered oil shale ash, due to their content of nutrients, has a certain promise even on the carbonate soils, although the neutralizing substances of these materials remain useless there.